Least-squares wave-equation migration of land data - synthetic results

- Providing high quality initial reflectivity model with squared excitation amplitude imaging condition

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Motivation

Least-squares wave-equation depth migration has been shown to produce seismic images with better quality over conventional migration. However, it still faces the challenge of high computation cost, as many migration iterations are involved. In the example of Figure 1, we need 15 iterations to achieve convergence, even though Hessian compensation is included. A straightforward way to reduce computation cost is to improve the quality of the initial reflectivity model. In our research, we propose a new squared excitation amplitude imaging condition to provide RTM (reverse-time migration) image as the initial reflectivity model with high resolution, fewer migration artifacts, small storage requirement, and properly scaled amplitude.

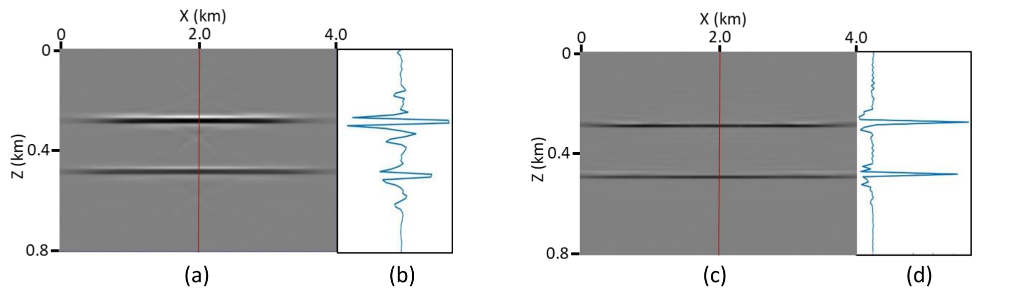

Figure 1. Least-squares PSPI migration of synthetic data. The least-squares migration (c) has better imaging quality over conventional migration (a). (b) and (d) are the single traces extracted from the center location.

Workflow

Our method is implemented with three key steps (Figure 2): 1) Excitation time, amplitude calculation and storage after source extrapolation, 2) Direction-preserved zero-lag autocorrelation of receiver wavefields, and 3) Application of squared excitation amplitude imaging condition.

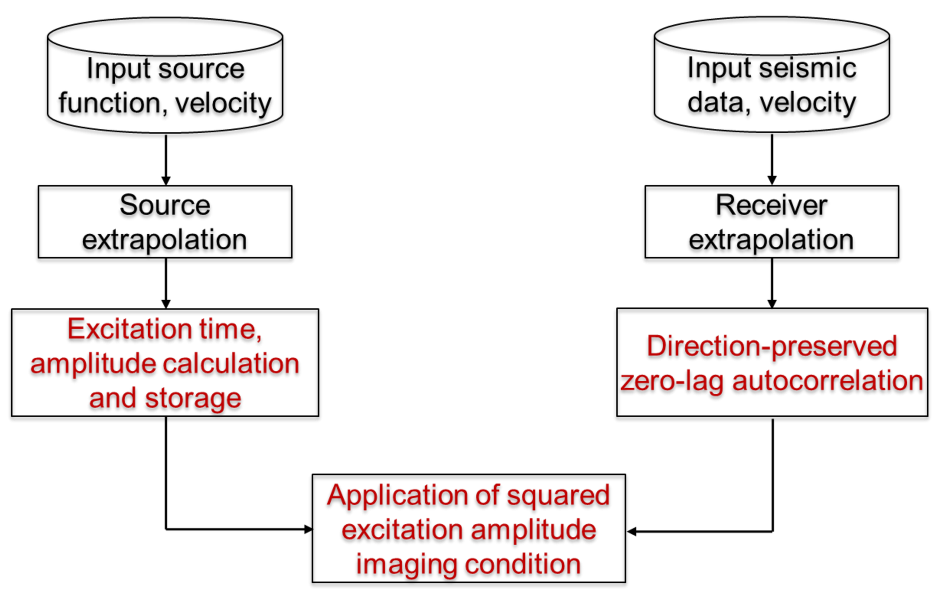

Figure 2. Workflow of the proposed method

Synthetic example

We implement numerical test on a multi-reflector model, to indicate the benefits of the proposed method.

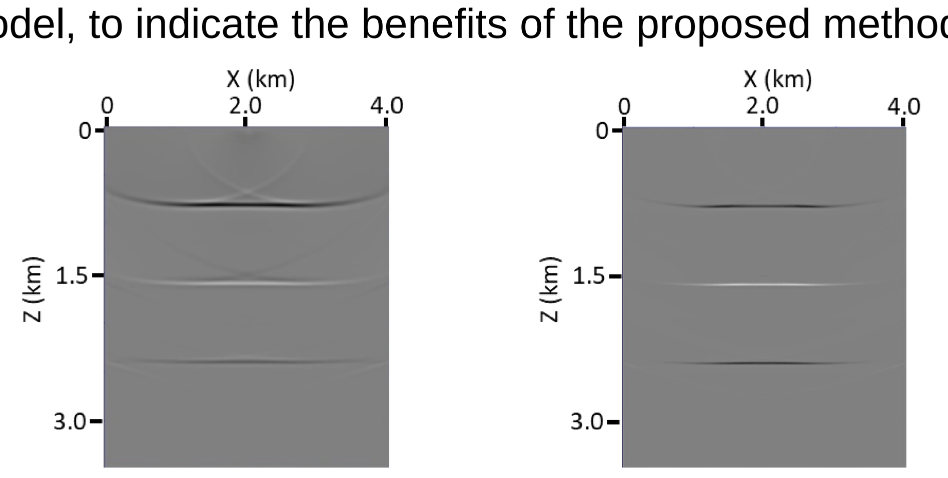

Figure 3. Single source RTM images with different methods

Imaging evaluation

Migration resolution

The comparison of the enlarged single trace images around the three reflectors (Figure 4) indicates the resolution improvement. Note that the duration times of the total wavelet and the main lobe are compressed, and the side lobes are reduced by using the proposed method.

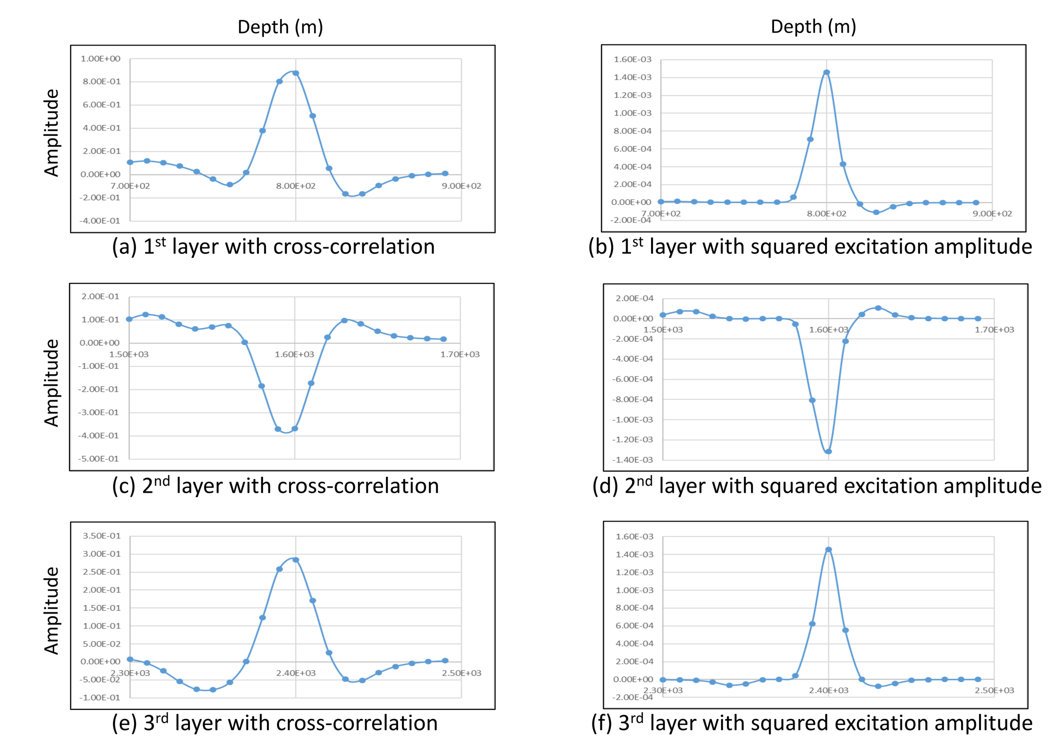

Figure 4. Comparison of migration resolution of the multi-reflector model

Migration artifacts

The migration artifacts are effectively suppressed with the proposed method, especially in the shallow part (Figure 5).

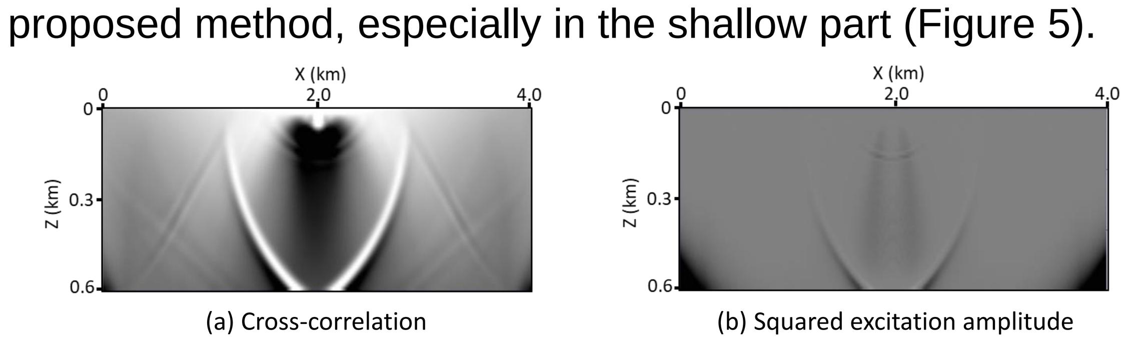

Figure 5. Comparison of migration artifacts for single source

Amplitude preservation

The squared excitation imaging condition could provide seismic image with properly scaled amplitude (Figure 6).

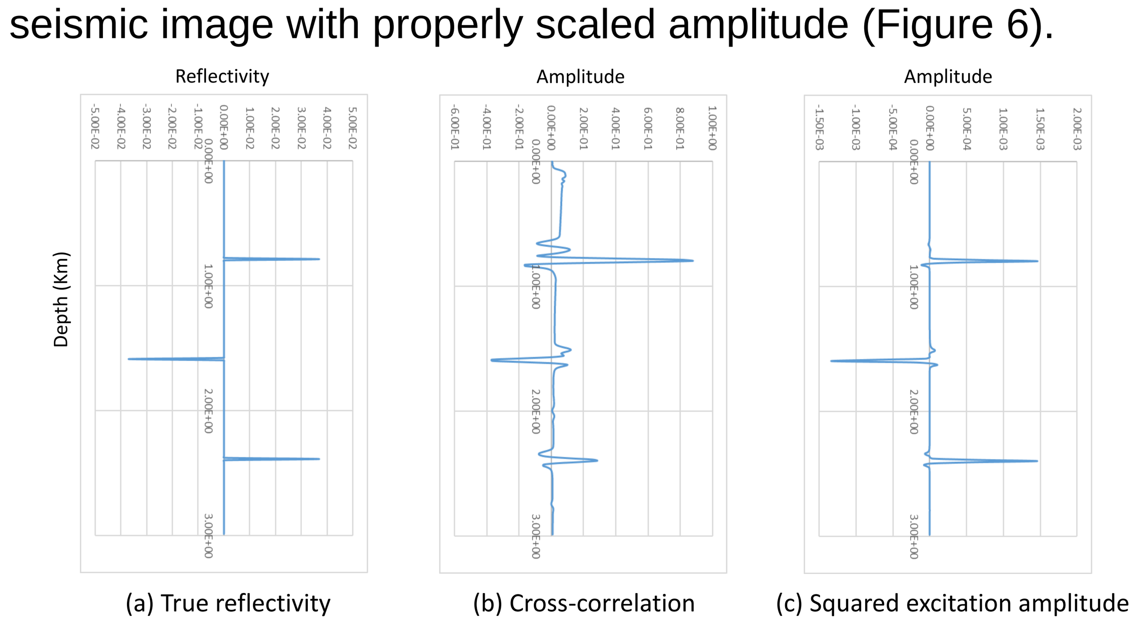

Figure 6. Comparison of amplitude preservation with single trace images

Storage requirements

The proposed RTM method has much smaller storage requirements over cross-correlation method (Figure 7).

Imaging condition	Cross-correlation	Squared excitation amplitude
Storage requirement	844200000 Bytes	562800 Bytes

Figure 7. Comparison of single source RTM storage requirement

Numerical tests

Thin-bed model

We design a thin-bed model with a horizontal reflector, a dipping reflector, a sub-sag structure, and **a thin 10m low velocity bed** at depth 3.52 km. The numerical test (Figure 8) indicates that the proposed method provides RTM image with fewer migration artifacts, and especially higher resolution, which is critical for the thin bed detection.

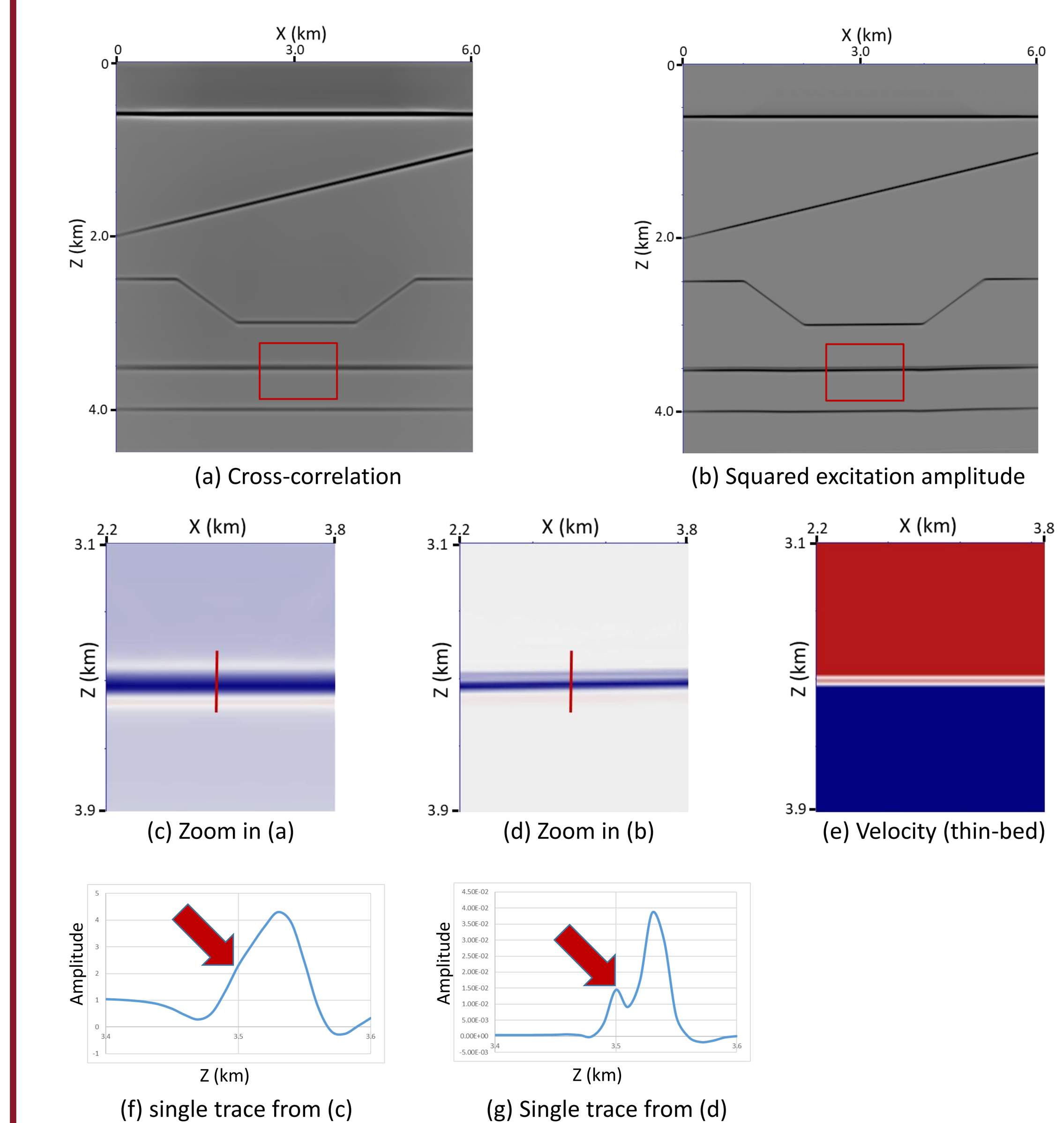

Figure 8. Numerical test of thin-bed model, note the thin bed indicator by the arrow.

Marmousi2 model

The numerical test of Marmousi2 model (Figure 9) indicates that the proposed method provides image with more focused energy and fewer migration artifacts. Especially, the thin layers are better resolved due to the higher imaging resolution.

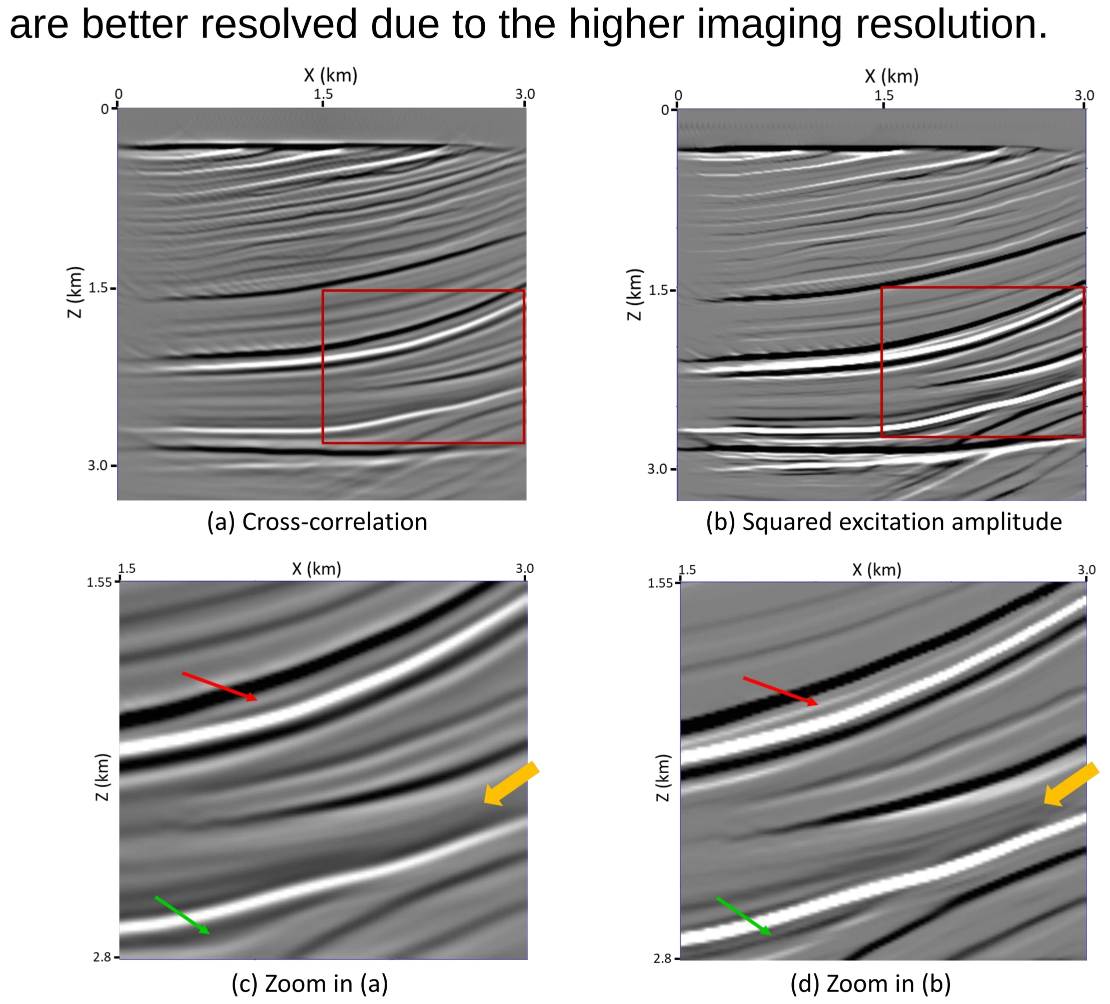

Figure 9. Numerical test of Marmousi2 model

Future work plan

In the next step, we will use the high-quality seismic images produced by the proposed method as the initial reflectivity model, which aims to reduce the iterations in the least-squares migration. Besides the large computation cost, there are several other challenges in the least-squares wave-equation migration of land data. The first one is the data interpolation of irregularly sampled 3D land surveys. Here, we will investigate various implementations of 5D interpolation, including those using a 3D linear moveout high resolution Radon transform. Another common challenge for land data imaging is the near surface problem. To deal with the statics, our solution is a two-step correction: First, we correct the high-frequency component of the roughed topography to a floating datum, followed by migration from this floating datum. Q estimation and compensation are also needed to handle the near surface attenuation challenge.

Conclusion

Increased computation cost remains one of the biggest challenges for least-squares wave-equation migration. In our study, we propose a new RTM method with a squared excitation amplitude imaging condition. It provides seismic images with higher resolution and fewer migration artifacts over conventional cross-correlation imaging condition. The numerical tests on a thin-bed model and the Marmousi2 model indicate the effectiveness of the proposed method. This high-quality seismic image could be used as the initial reflectivity model for least-squares wave-equation migration, to reduce the migration iterations.

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References

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